CHAPTER 6

CHARACTERISTICS OF NATURAL STREAMS

Section I. General

6-1. Natural Streams. Natural streams can be characterized by their tendency to meander and migrate, irregularity and changing geometry, varying stage and discharge, and variations in the composition of bed and banks. Because of these variations, no two reaches are exactly t same. Many of the problems encountered in the development and improv ment of natural streams are concerned with channel alignment and the movement of sediment into and within the stream. Scouring of the bed and banks and deposition in critical areas can affect channel depth a alignment and the operation and use of facilities and structures for navigation such as locks, harbors, docking areas, and other facilitie such as hydroplants, sewage systems, and water intakes. Sediment mov ment can also affect the capacity of the channel to pass flood flows.

6-2. Sedimentation Problems. Since sedimentation problems can affec the type of waterway that could be developed and construction and mai tenance cost, it is important that they be recognized and considered. The movement of sediment in natural streams is extremely complex depe ing on many factors, most of which are interrelated. Solution of sed mentation problems requires a knowledge of the general characteristic of the stream and of the principles of river sedimentation processes.

6-3. Sediment Load. Considerable research on the movement of sedime has led to a better understanding of the mechanics of sedimentation a to the development of theories and formulas. Most of what has been written on the subject has been based on two-dimensional flow and is general to have any practical application in the solution of most riv problems. The total sediment load of streams has been based on measurements using various sampling methods or computations using one of several available sedimentation formulas. The accuracy of measuremen would depend on the number of measurements covering a wide range of discharge and is affected by the difficulty of measuring sediment moving as bed load. Sediment computations are generally based on averag conditions and could be in error by a sizable amount because of the variations in the factors involved such as slope, depth, velocity, an discharge. Even if sediment measurements and computations could be made with a high degree of accuracy, a satisfactory method of using t information in the solution of most practical open-river problems has not yet been developed.

6-4. Third Dimension. The movement of sediment in a stream has to be considered in three dimensions. The third dimension is provided by the Franco principle of lateral differential in water level. This principle is stated as follows: "When conditions are such that a lateral differential in water level (or transverse slope) exists or is produced by changes, there will be a tendency for at least some of the total flow to move toward the lower elevation; the slower moving, sediment-laden bottom currents can make the change in direction easier than the faster moving surface currents and account for the greater concentration of sediment moving toward the lower elevation." This general principle is involved in many of the developments in alluvial streams including the development of sandbars on convex side of bends, movement of sediment around the end and behind dikes, development of cutoffs and divided channels, shoaling in lock approaches, etc. In each case there is either a buildup in water level on one side or a reduction caused by channel enlargement, contraction, or flow diversion that causes some of the flow to change direction.

Section II. Shoaling Problems

6-5. Deposition. Shoaling problems affecting channel width, depth, and alignment can be encountered in any stream carrying sediment. These problems can usually be expected in crossings, long straight reaches or in long flat bends where the low-water channel tends to be unstable, at mouths of tributary streams, in reaches where there is divided flow or bifurcated channels, in lock approaches, and in entrances to slack-water canals or harbors. Most shoaling problems are local and solution of these problems requires a knowledge of the characteristics of the reach under study, the reach just upstream, to a lesser extent the reach just downstream, and the factors affecting the movement of sediment in these reaches. The design engineer should be concerned more with the sediment contributing to the problem, flows during which the problem or problems develop, and the principles involved in its development than in the total sediment load moving through the reach. Generally, the sediment forming the shoal is only a very small part of the total sediment load but can be sufficient to create problems for navigation.

6-6. Stage and Discharge. Changes in the discharge and stages produce changes in currents and in the movement of sediment that render the application or development of design principles extremely difficult. Model and field investigations have indicated how channel depths and configurations can be altered with change in stages. The movement of sediment in one reach can be considerably higher than in a reach just downstream during low flows and considerably lower during high flows.

When one reach is not capable of moving the entire sediment load, shoaling will occur in that reach until velocities, slopes, and carrying capacity of the channel increase to that required to move the load.

6-7. Low-Water Profiles. Changes in low-water slope profiles are usually indications of the relative amount of sediment movement in successive reaches. When the low-water slope in a reach is substantially higher than the average, it is generally an indication that more sediment was moved into that reach from upstream during the higher flows than could be moved through the reach during the same and subsequent flows. Unstable and troublesome reaches will tend to have a higher-than-average low-water slope.

6-8. Meandering Channels. Natural streams having erodible bed and banks will tend to meander, developing a sinuous course consisting of a series of alternate bends and crossings with some relatively straight reaches. The degree of sinuosity assumed by these streams depends on many factors including discharge, sediment load, valley slope, and composition of bed and banks. Unless the meandering of these streams is resisted by stabilization and training works, the bends will tend to migrate and change through the erosion and caving of their banks and the process of channel erosion and deposition. The channel is deeper in bends along concave banks and shallower in crossings and straight reaches (fig. 6-1).

6-9. Scour in Bends. The channel in bends tends to deepen during high river stages. Scour generally starts near the upper end of the bend and progresses toward the downstream as discharge and river stages increase. The increase in depth can be as much as one half to more than the amount of increase in stage, depending on the curvature of the bend and alignment of the channel upstream. With other conditions remaining the same, the increase in depth appears to be more a function of the river stage and stage duration than of the rate of change in stage. Where depths increase with river stage, shoaling of the channel starts during the falling stages near the upper end of the bend and continues toward the downstream during the low-water period.

6-10. Sediment Movement. The scouring of the channel in bends can cause a large amount of sediment to move into the crossing and reach just downstream. Because of the concentration of high-velocity currents and turbulence in bends, much more sediment can be moved in sinuous channels than can be moved in straight channels with the same average velocity and slope. For this reason straight channels and crossings downstream of a bend will tend to be shallow and unstable. Low-water slopes through bends are generally lower than the average because of the

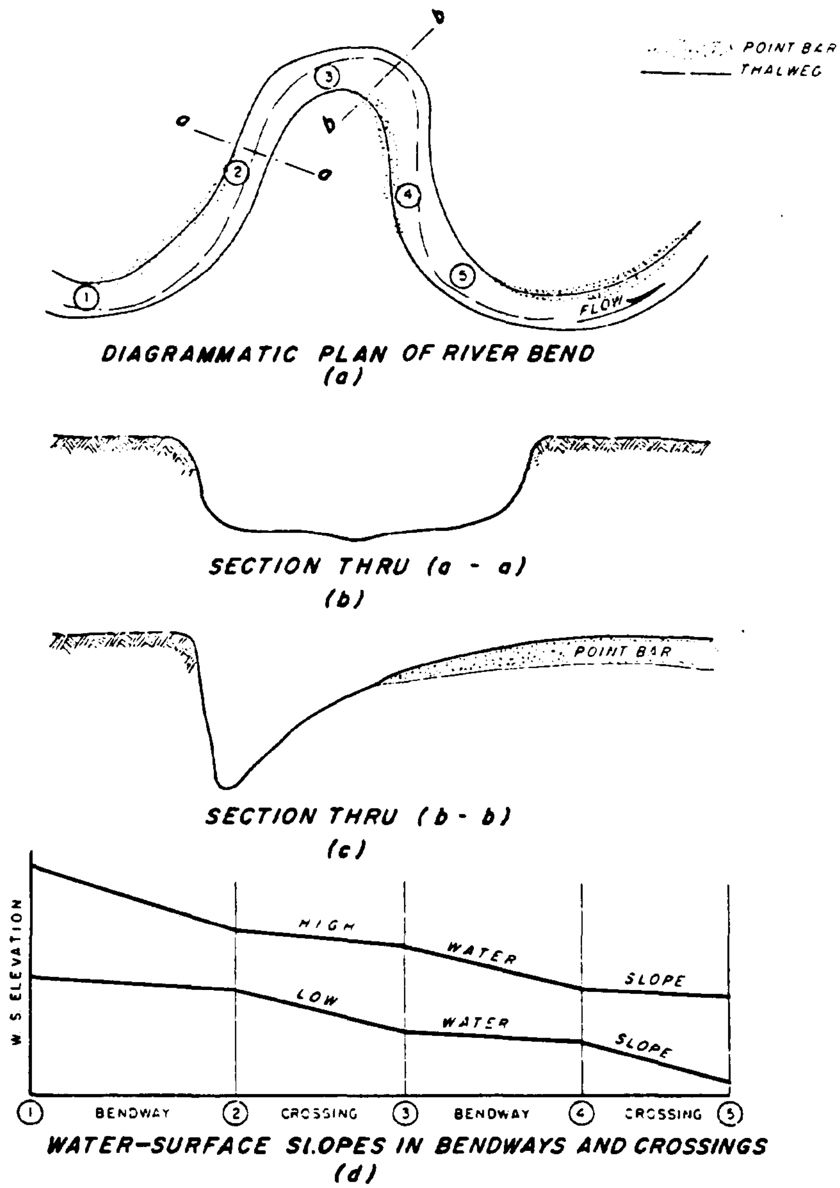

Figure 6-1. Characteristics of a river reach

backwater effect produced by the shallow crossing downstream (fig. 6-1d). Because of the reduced slopes and velocity, deposition occurs in bends during low flows. However, the amount of deposition is seldom sufficient to reduce depths to less than that required for navigation.

6-11. Crossings. In meandering streams the low-water channel in the straight reach between alternate bends crosses from one side of the river to the opposite side (fig. 6-2). Because the movement of sediment in a bend is greater than the capacity of the straight channel downstream during the higher flows, deposition occurs in the crossing, limiting depths available for navigation. As river stages decrease, slopes and velocities over the crossing tend to increase, increasing the movement of sediment and depths. The rate of scour and depths available for navigation depend on the stage and stage duration. After a prolonged high-water period or after a rapid decrease in stage, depths over crossings will tend to limit channel depths available and are a frequent source of navigation difficulties. Alignment and depth of the channel in crossings depend on variations in flow conditions and alignments of the reaches upstream and downstream. Maintaining a satisfactory channel in crossings will be more troublesome if regulating structures on the concave side of the bend upstream are not carried far enough downstream to prevent dispersion of the higher flows and if the crossings to the next bend are relatively long. Extending the training works in a bend toward the crossing downstream improves the alignment and depth of the channel over the crossing and flow into the bend downstream.

6-12. Straight Channels. Channels in long straight reaches or in long flat bends will tend to meander within their banks and be unstable and troublesome. Development and maintenance of a satisfactory channel through these reaches are more difficult than in a sinuous reach and could be affected by variations in discharge, relative sediment-carrying capacity of the reach upstream, or sand waves moving through the reach. Unstable and troublesome reaches will tend to have a higher low-water slope than will stable reaches.

6-13. Divided Channels. Bifurcated channels or divided flow will be found in many alluvial streams in addition to those formed by cutoffs. Side channels will tend to carry a greater proportion of the sediment load than the proportional discharge, because of the lateral differential in water level which depends upon the shape, size, and angle of entrance with respect to the direction of flow from upstream and the relative lengths of the two channels. When the entrance to the side channel is wide in comparison with the rest of the channel, sediment will tend to be deposited near the entrance, which could eventually

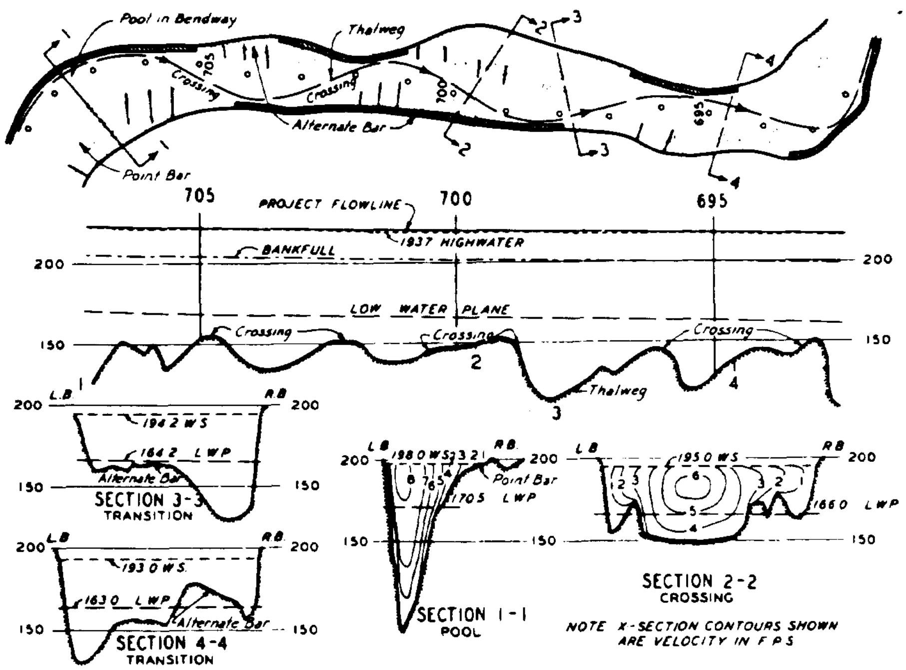

Figure 6-2. Features of a typical improved reach--Mississippi River

reduce or eliminate flow through the channel during low stages. Depths in the main channel will tend to be limited when side channels carry a sizable proportion of the total flow; and the partial or full closure of these channels will be required to improve depths in the main channel. When deposition occurs near the entrance, the sediment-free flow moving downstream of the entrance could cause scouring and deepening of the side channel and bank caving. When there is a substantial amount of flow diverted through a side channel, the main low-water channel will tend to develop toward the point of diversion (fig. 6-3).

6-14. Tributary Streams. Flow from tributary streams causes a local increase in water level just upstream and channelward of the inflow and a lowering of the water level along the adjacent bank downstream. The difference in water level will depend on the discharge, and current direction and velocities of the flow entering the main stream. Because of the lateral differential in water level created, there will be a tendency for shoaling along the adjacent bank downstream and for sediment carried by the tributary to be moved along that side of the channel. Accordingly, the deeper channel will tend to form away from the adjacent bank (fig. 6-4).

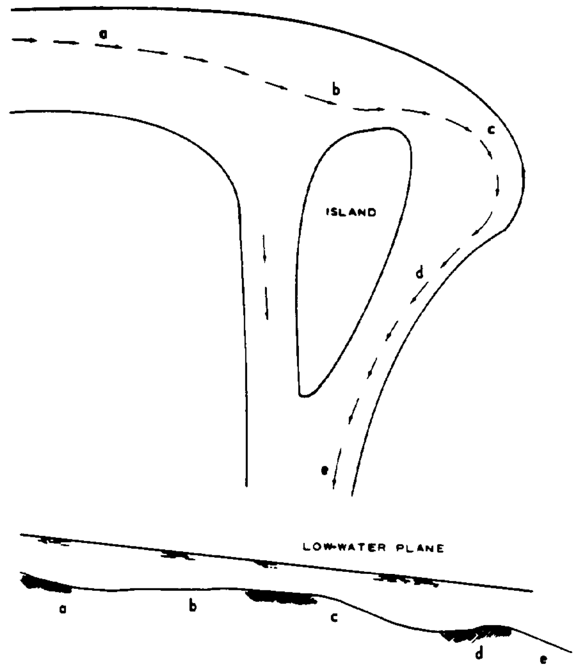

Figure 6-3. Typical divided channel

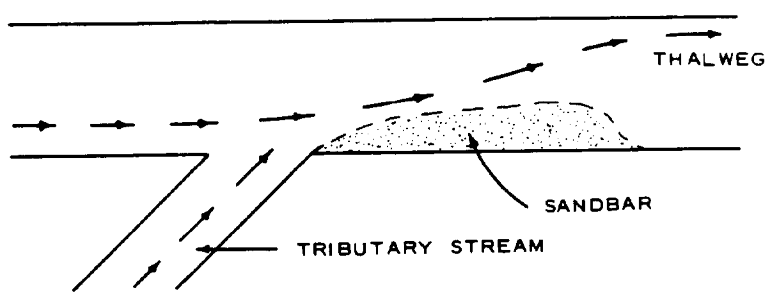

Figure 6-4. Effect of tributary on channel configuration

6-15. Entrances to Canals and Harbors. Entrances to canals and slack-water harbors involve openings in the bank line and a local increase in the channel width. This causes a lowering of the water level at the entrance and a tendency for bottom currents and sediment to move toward the entrance, resulting in a tendency for shoaling. The amount of shoaling will depend on the amount of sediment carried by the stream, size of the entrance, and location of the entrance with respect to the alignment of the stream channel. Shoaling in the entrance could also be affected by the rate of rise and fall of river stages which cause flow toward and away from the canal or harbor (fig. 6-5).

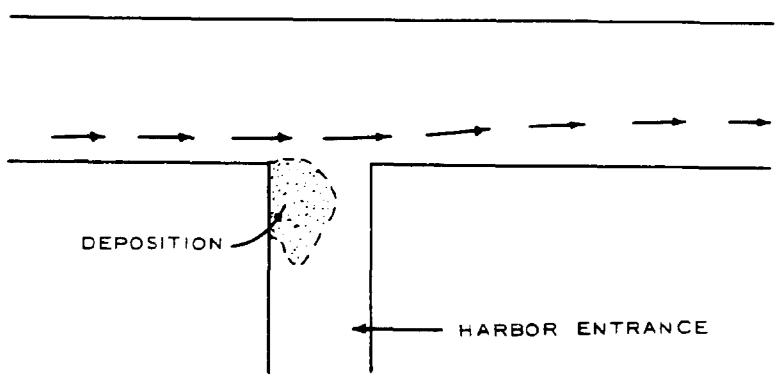

Figure 6-5. Shoaling in harbor entrance located along riverbank